

Studies on the Cerebral Arteries of *Macacus cyclopsis*

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Received for publication February 25, 1961

A gross anatomical study on the distribution, course and branches of the cerebral arteries of 19 brains (38 cerebral hemispheres) from adult *Macacus cyclopsis* was done and compared with the reported results for man and other primates.

The cerebral arterial system in *Macacus cyclopsis* is supplied by the A. carotis interna and A. vertebralis.

The A. carotis interna separates into two terminal branches, the A. cerebri anterior and A. cerebri media. The A. cerebri anterior of each side unite to form the A. cerebri anterior communis. Prior to this union, the A. communicans anterior, which connects the A. cerebri anterior of each side, is seen in some cases.

The A. vertebralis of each side unite to form the A. basilaris and its terminal branch becomes the A. cerebri posterior.

Since the A. communicans posterior, which connects the A. carotis interna and A. cerebri posterior, is present, the so-called circulus arteriosus is formed at the base of the brain. This circulus arteriosus may be classified into two types; that in which the A. communicans anterior plays a role and that in which it does not. The most common type is that in which the A. communicans anterior does not play a role.

The cerebral arteries of primates have been studied by GRUMBAUM and SHERRINGTON (1902), ROTHMANN (1904), SHELLSHEAR (1927, 1930), HINDZE (1930), WATTS (1934), etc., while the cerebral arteries of *Macacus cyclopsis* specifically have been investigated by HATTA (1936). These works, however, are simply comparative anatomical studies on a small number of cases. In any attempt to determine the most common condition, in other words, the normal state of some species of animal, it is obviously necessary to investigate the greatest possible number of cases with a statistical approach. As a part of the anatomical study on *Macacus cyclopsis* being continued in this department, I have recently investigated the cerebral arteries. My findings shall be presented in the following text.

MATERIAL AND METHOD

The material consist of adult *Macacus cyclopsis* from the collection

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of Prof. SATOH. After capture, these animals have been strangled and immediately fixed by the injection of 10% formaline solution into the A. femoralis, and preserved in this 10% solution. A total of 38 cerebral hemispheres from each side of 9 male and 10 female animals were examined.

The A. carotis interna, A. basilaris and A. vertebralis were primarily investigated with careful observations with magnifying lenses of the branchings, the differences in diameter of the vessels on each side, the course, distribution, etc. In addition, measurements were taken when necessary.

FINDINGS AND CONSIDERATION

The cerebral arterial system of *Macacus cyclopsis* is supplied by the A. carotis interna and A. vertebralis.

The A. carotis interna enters the cranium after penetrating the dura mater at the base of the brain. Between the chiasma opticum and lobus temporalis, it gives off the A. communicans posterior, and then separates into its two terminal branches; the A. cerebri anterior and A. cerebri media. The A. cerebri anterior on each side unite near the fissura longitudinalis cerebri to become the A. cerebri anterior communis.

The A. vertebralis of each side, after entering the cranium in the region of the lower tip of the medulla oblongata, unite, in the area of the medulla oblongata or the border between the pons and the medulla oblongata, to form the A. basilaris, which separates, at the upper tip of the pons, into two terminal branches to each side that run lateralward and become the A. cerebri posterior.

The connection of the A. carotis interna and the A. vertebralis by the A. communicans posterior, which is a branch from the A. carotis interna, results in the formation of the circulus arteriosus cerebri.

I. A. CAROTIS INTERNA

This artery penetrates the dura mater and passes between the chiasma opticum and lobus temporalis where it gives off the A. ophthalmica, which runs along the lateral side of the N. opticus. After further small branches to the lower surface of the tractus opticus and corpus mamillare are sent off, it separates into two branches; anterior and posterior.

The anterior branch runs antero-lateralward and, after giving off the A. chorioidea anterior, separates at the lateral side of the tractus opticus, into its terminal branches; the A. cerebri anterior and A. cerebri media.

The posterior branch becomes the A. communicans posterior and unites with the A. cerebri posterior, which is a branch of the A. basilaris.

There is no gross difference in the size of this artery measured immediately before the origin of the A. communicans posterior.

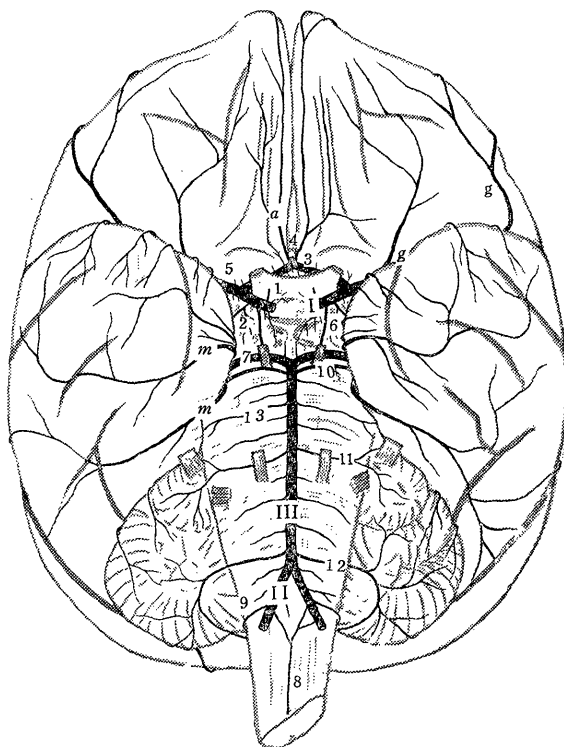


FIG. 1 Base of brain

- I) A. carotis interna
- II) A. vertebralis
- III) A. basilaris
- 1) A. ophthalmica
- 2) A. chorioidea anterior
- 3) A. cerebri anterior
- 4) A. cerebri anterior communis
- 5) A. cerebri media
- 6) A. communicans posterior
- 7) A. cerebri posterior
- 8) A. spinalis anterior
- 9) A. spinalis posterior
- 10) A. cerebelli superior
- 11) A. cerebelli inferior anterior
- 12) A. cerebelli inferior posterior
- 13) Rami ad pontem
- a) A. olfactoria anterior
- g) Rr. ascendentes anterior
- m) Branch arising from part of Uncus gyri hippocampi
- n) Branch inters to Fissura calcarina

The findings described above are very similar to that reported for man (HASEBE, KONDO, etc.) and other primates (WATTS).

1 A. ophthalmica

A conspicuous, comparatively well developed artery is given off from the A. carotis interna immediately after it enters the cranium by penetrating the dura mater at the base of the brain. This artery, on each side, run forward on the lateral side of the chiasma opticus and becomes the A. ophthalmica. It was absent in no case.

As described above, this artery in the cases that I have investigated was comparatively well developed. This artery has been generally reported to be well developed in man and in monkey (HATTA). However, in *Macacus rhesus* it is said to be poorly developed and the condition is more similar to that in other mammals in which it is distributed to only one part of the pars orbitalis (UEDA).

2 A. chorioidea anterior

The location of the origin of this artery from the A. carotis interna was always slightly lateral to that of the A. communicans posterior. It runs backwards and downwards along the lower surface of the tractus opticus and, as it alters its course upward, it gives off slender branches to the tractus opticus and uncus gyri hippocampi. It then emerges into the plexus chorioideus ventriculi lateralis.

In man, this artery is given off from the A. carotis interna slightly lateral to the A. communicans posterior (HASEBE, ITAHASHI, KONDO). Exactly the same condition was found in my study of *Macacus cyclopsis*. My findings on the course and state of branching of this artery are essentially the same as that for *Macacus fuscata* (HATTA) and *Macacus rhesus* (UEDA).

II. A. CEREBRI ANTERIOR

A) The anterior branch of the A. carotis interna separates into two on the lateral side of the N. opticus. The A. cerebri anterior, the lateral of the two, runs antero-medialward between the chiasma opticus and trigonum olfactorium to the fissura longitudinalis cerebri. Before reaching the front of the genu corporis callosi, the vessels on each side join, usually in front of the area subcallosa to form the A. cerebri anterior communis. In rare cases, prior to this formation of the A. cerebri anterior communis by the union of the artery on each side, the A. communicans anterior, which connects the two, may be found (10.4%) but even in these cases, the vessels on each side unite to form a single trunk in the fissura longitudinalis cerebri.

In man, the A. cerebri anterior on each side, before they enter the fissura longitudinalis cerebri, are connected by the A. communicans anterior but the A. cerebri anterior on each side never join to form the A. cerebri anterior communis. In this sense, the abnormal cases seen among my sample of *Macacus cyclopsis* are similar to man.

Comparison of the diameter of the vessels on each side revealed them to be equal in the majority of cases (68.4%) followed in frequency by cases in which the right is larger (26.4%) with only a few cases in which the left side is larger (5.2%).

Prior to the formation of the A. cerebri anterior communis, the following branches are given off.

1. Rami perforantes

These are small branches which arise near the origin of the A. cerebri anterior. They run antero-lateralward and together with the rami perforantes of the A. cerebri media, supply the area about the substantia perforata anterior and the trigonum olfactorium. Some of them penetrate and enter directly inside.

2. A. olfactorium lateralis

This artery is given off anterolaterally before the A. cerebri anterior on each side unite and form the A. cerebri anterior communis, which runs in the fissura longitudinalis cerebri. It runs forward toward the polus frontalis along the trigonum olfactorium and lower surface of the tractus olfactorius and terminates in the bulbus olfactorius. During its course, small branches are sent off on the lower surface of the tractus

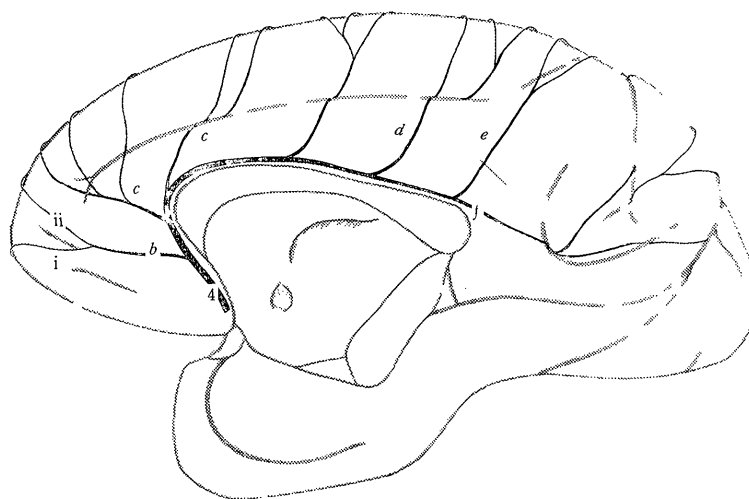


FIG. 2 Medial surface of cerebral hemisphere

- 4) A. cerebri anterior communis
- b) A. marginalis
 - i) Praefrontal branch
 - ii) Fronto-polar branch
- c) Branch to medial surface of Lobus frontalis and Gyrus frontalis superior
- d) Branch to Sulcus centralis and Sulcus praecentralis
- e) Branch to Sulcus postcentralis and Sulcus intraparietalis
- f) A. corporis callosi

olfactorius which run toward the gyri orbitales and the terminal branch in some cases extend to the polus frontalis.

This artery is absent in man but is reported to be particularly conspicuous in *Macacus cyclopsis* and *Macacus fuscata* (HATTA) which agree with my findings for *Macacus cyclopsis*. However, it has been reported that it is poorly developed and only rudimentary in *Macacus rhesus* (UEDA).

B) The A. cerebri anterior communis, as it progresses anterosuperiorly in front of the ventriculi tertius near the surface of the area subcallosa, sends off small branches to the area subcallosa, gyrus paraterminalis, etc. After reaching and passing around the lower surface of the genu corporis callosi, it runs along the sulcus corporis callosi on the dorsal surface of the corpus callosum. The cortical branches, which supply the medial surfaces as well as the superior surface of the lobus frontalis and lobus parietalis of each hemisphere, are given off. After reaching the splenium corporis callosi, it separates into its terminal branches to each side, the A. corporis callosi, which supply the respective hemispheres. The following additional branches are sent off.

1. A. marginalis

Immediately after the formation of the A. cerebri anterior communis by the union of the A. cerebri anterior, a large branch to each side is given off in front of the rostrum corporis callosi which soon separates into two branches; superior and inferior. The inferior branch passed around the lower edge of the brain and supplies the pars orbitalis of the lower surface of the lobus frontalis. It then proceeds further along the gyrus rectus and passes around the lower surface of the Lobus frontalis to the outer surface of the brain (prae-frontal branch). The other superiorly located branch runs anterosuperiorward. During its course, as it passes around the edge of the polus frontalis, it gives off small branches to the medial surface of the lobus frontalis. The terminal branch extends further and supplies the outer surface of the lobus frontalis (fronto-polar branch). Cases in which these two branches arise from the A. cerebri anterior communis as independent branches and not by a common trunk were comparatively few (5.2%).

2. Branches arising between the genu corporis callosi and the origin of the A. corporis callosi

i) There generally are three major branches which arise from this area and supply the medial surface of the lobus frontalis and gyrus frontalis superior. The first and second branches, which are located anteriorly, both arise near the genu corporis callosi. The first branch runs across the gyrus cinguli, passes the anterior edge of the sulcus cinguli, and runs around the edge of the brain to emerge in the gyrus frontalis superior and outer surface of the lobus frontalis to supply the polus frontalis and sulcus rectus. The second branch, like the first branch, passes the gyrus cinguli and enters the sulcus cinguli which it

supplies. It extends further, passing through the gyrus frontalis superior to the outer surface of the lobus frontalis and ends at the upper edge of the sulcus arcuatus. The third branch arises slightly anterior to the central part of the corpus callosum and, similar to the first and second branches, passes through the gyrus cinguli to the sulcus cinguli where it branches out to be widely distributed in the area in front of the sulcus praecentralis.

There are, however, occasional cases in which only two branches are found: The second branch may be absent and compensated by a division of the third branch (10.4%) or the third branch may be absent and compensated by a division of the second branch (5.2%). In some cases there are four branches (5.2%), or as many as fine branches (5.2%). The branch corresponding to my third branch has not been described in the study of *Macacus cyplopes* by HATTA.

ii) Next, a branch running toward the sulcus praecentralis and sulcus centralis is given off to each side at about the middle of the posterior surface of the corpus callosum. It ascends in the gyrus cinguli to the sulcus cinguli from where it runs along the lobulus paracentralis and around the edge of the brain to the outer surface. It primarily supplies the sulcus praecentralis and sulcus centralis.

Although this branch was absent in none of the cases, it was a division of the previously described second branch which supplies the medial surface of the lobus frontalis and gyrus frontalis superior in the left hemisphere of one case (5.2%).

iii) There is a further branch running toward the sulcus postcentralis and sulcus intraparietalis. This branch in most instances arises near the splenium corpus callosum and passes through the pars marginalis of the sulcus cinguli to beyond the edge of the outer surface. It is principally distributed to the sulcus postcentralis and sulcus intraparietalis. During its course, small branches are sent off to the lobulus paracentralis. Although the origin of this branch in most cases is near the splenium corpus callosum as described above (right hemisphere 46.8%, left hemisphere 76.2%), it is noted at a considerable frequency to arise from the terminal branch of the A. cerebri communis, i.e. the A. corporis callosi (right hemisphere 31.5%, left hemisphere 26.3%) while in some cases it arose from the previously described branch to the sulcus centralis (right hemisphere 10.4%) or from the lateral branch which is given off near the middle of the corpus callosum from the A. cerebri anterior communis (right hemisphere 10.4%).

3. A. corporis callosi

The A. cerebri anterior communis, as it gives off the above branches, runs to the vicinity of the splenium corporis callosum to become the terminal branch, the A. corporis callosi.

The terminal branch of the A. cerebri anterior communis passes around behind the splenium corporis callosum and as it runs backward and upward, it gives off small branches. It then separates into two branches. The upper branch continues to run backward and upward, giving off small branches to the surface of the precuneus during its course and passes around the edge of the brain to supply the sulcus parieto-occipitalis and occasionally the sulcus lunatus. On the other hand, the lower branch as it runs backward and upward along the sulcus calcarina gives off small branches to the precuneus, cuneus and sulcus calcarina. It passes through the sulcus parietooccipitalis and around the posterior edge of the brain to the outer surface and supplies the outer surface of the lobus occipitalis. In rare cases, this lower branch is absent (right hemisphere 5.2%, left hemisphere 5.2%).

UEDA reports that in half of his cases of *Macacus rhesus*, this artery extended to the middle third of the precuneus, while in the remaining half, it reached as far as the cuneus. In his comparison with the condition in *Macacus cyclopsis* and *Macacus fuscata* as reported by HATTA, it was said that the state of distribution approached that of man in the order *Macacus rhesus*, *Macacus cyclopsis* and *Macacus fuscata*. However, my findings do not indicate *Macacus cyclopsis* to be more primitive than *Macacus fuscata*.

Review of the state of the A. cerebri anterior and A. cerebri anterior communis in mammals shows that they may be classified into two types: That is, one in which the A. cerebri anterior on each side do not unite to form the A. cerebri anterior communis but run independently along the medial surface of each cerebral hemisphere with connection between the A. cerebri anterior on each side by the A. communicans anterior as is the condition in man. The other type is one in which, regardless of whether there is the A. communicans anterior, the A. cerebri anterior on each side unite to form the A. cerebri anterior communis as was seen in my cases of *Macacus cyclopsis*. In *Cebidae*, *Macacus mulatta*, *Macacus fuscata*, *Macacus cyclopsis*, *Hylobates* (WATTS, HATTA, UEDA, etc.), the A. cerebri anterior communis is formed in the fissura longitudinalis cerebri. In *Anthropithecus niger* (WATTS, ROTHMANN, HINDZE, SHELLSHEAR, GRUMBAUM and SHERRINGTON) the A. cerebri anterior communis is formed in the majority of cases with separation into the A. cerebri anterior to each side in the vicinity of the splenium corporis callosum. However, there are some cases in which there are independent arteries on each side running on the medial surface of the cerebral hemisphere along the corpus callosum (ROTHMANN). On the other hand, in *Simia satyrus* (WATTS, GRUMBAUM and SHERRINGTON) and *Gorilla gorilla* (ROTHMANN), the A. cerebri anterior communis is not formed just as in man. ROTHMANN reports that the condition may be classified into the lower monkey type in which there is the formation of the A.

cerebri anterior communis and the human type in which there is no formation of the A. cerebri anterior communis. In anthropoid ape, the state is still of the monkey type with progressively increasing frequency of the human type in *Anthropithecus niger*, *Simia satyrus* and *Gorilla gorilla*. All cases of *Macacus cyclopsis* were of the so-called lower monkey variety.

III. A. COMMUNICANS ANTERIOR

As described previously, the A. cerebri anterior of each side generally unite soon after entering the fissura longitudinalis cerebri to form the A. cerebri anterior communis (Type II). In rare cases, prior to this union, an artery connecting the A. cerebri anterior on each side. i.e., the A. communicans anterior, is noted (10.4%, Type I a,b). In one case (Type I b), a transverse Y-shaped A. communicans anterior was seen connecting the A. cerebri anterior prior to the formation of the A. cerebri anterior communis at the entrance of the fissura longitudinalis cerebri while in the other case (Type I a), there was simply a linear connection between the two by a communicating branch at the entrance of the fissura longitudinalis cerebri.

Consequently, the state of connection between the A. cerebri anterior, the A. communicans anterior and the A. cerebri anterior communis in the *Macacus cyclopsis* may be classified into the following two types.

Type I (Type Ia,b): The A. cerebri anterior of each side unite in the fissura longitudinalis cerebri to form the A. cerebri anterior communis but prior to this union, there is the A. communicans anterior connecting each A. cerebri anterior.

Type II: The A. cerebri anterior of each side unite in the fissura longitudinalis cerebri to form the A. cerebri anterior communis without the presence of the A. communicans anterior.

Type II is the common pattern in *Macacus cyclopsis* (89.6%) with only rare cases of type I (10.4%).

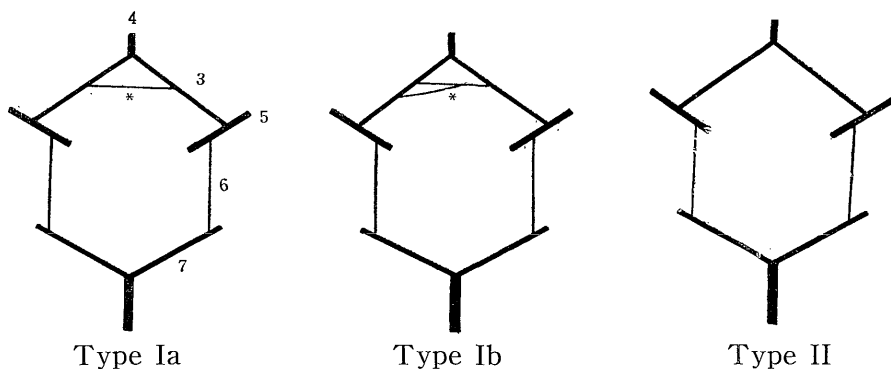


FIG. 3 Types of Circurs arteriosus

* A. communicans anterior

The A. communicans anterior has been reported to be absent in *Cebidae*, *Cercopithecidae*, *Hylobatidae* (WATTS, STAUNIUS, THEILE, ROTHMANN, HATTA, etc.). There is no mention of this artery in *Macacus fuscata* (HATTA) or *Macacus rhesus* (UEDA) which are in the same family as the *Macacus cyclopsis* nor is it described in the report by HATTA, on *Macacus cyclopsis*. The discrepancy with my findings is considered to be due to the small number of cases in their study. In *Hylobates*, this artery apparently is present in some cases (SPERINO, WALDEYER) but absent in others (WATTS, ROTHMANN). Though there are instances in which it is absent in *Simia satyrus* (BALK) and *Anthropithecus niger* (WATTS) in general, the condition in such anthropoid ape as *Simia satyrus*, *Anthropithecus niger* and *Gorilla gorilla* is very similar to man with the A. communicans anterior being present (ROTHMANN, WATTS, HINDZE, SPERINO, SHELLSHEAR, GRUMBAUM and SHERRINGTON). However, in human fetus, this A. communicans anterior is absent in a considerable number of cases (HIGETA). Therefore, though this artery is absent in *Cebidae*, it is rarely present in *Cercopithecidae* with increasing frequency of its presence in *Hylobatidae* while in *Pongidae* it is rarely absent just as in man.

IV. A. CEREBRI MEDIA

This artery on each side is almost always of equal side (94.6%) and larger than the A. cerebri anterior. It appears to be the direct continuation of the A. carotis interna. It always originates and terminates by one trunk and in no case did it separate into two during its course or arise by two trunks.

It runs lateralward in the vallecula lateralis cerebri, through the sulcus lateralis and runs around the edge of the brain to the outer surface of the lobus occipitalis where it is distributed. HATTA has described the origin of the A. cerebri media in two gross categories; that in which it assumed the form of the direct continuation of the R. anterior and that in which it was a lateral branch of the vessel connecting the R. anterior and the A. cerebri anterior. The findings in my cases of *Macacus cyclopsis* correspond to the direct continuation with the R. anterior and is the same as in *Macacus fuscata* and *Macacus rhesus*.

During its course, branches are given off to the substantia perforata anterior, lower surface of the lobus frontalis and polus temporalis, uncus gyri hippocampi, outer surface of the lobus frontalis, sulcus praecentralis, sulcus centralis, sulcus postcentralis, lobus temporalis, sulcus occipitalis and sulcus lunatus. These branches may be grossly classified into those which arise prior to the entry into the sulcus lateralis and those which are sent off in the sulcus lateralis.

1. Branches given off prior to entry into sulcus lateralis

i) Aa. striatli mediales

This artery arises in most cases by a common trunk with the Rr. ascendentes to be described below. There are, however, cases in which it arises independently. Together with the R. perferantes from

the A. cerebri anterior; it penetrates into the substantia perforata anterior. The terminal end usually separates into several twigs to form a cluster like pattern.

ii) Rr. ascendentes anteriores

This artery arises as one long branch after the separation of the R. perforantes and during its course divides into two branches. One supplies the sulcus orbitalis, gyrus orbitalis, olfactoria tract, etc. while the other ascends to the polus frontalis.

iii) Branches to the sulcus hippocampi and medial surface of the polus temporalis

Immediately after the A. cerebri media arises from the A. carotis interna, several small branches are given off backward. They are located in the region of the uncus gyri hippocampi, front end of the polus temporalis and dorsal surface of the polus temporalis. They later run to the medial surface and spread out.

2. Branches which separate in the sulcus lateralis

i) Branches distributed to the lobus frontalis

One to four branches are seen supplying the lobus frontalis. Four branches were seen in the left hemisphere of two cases (10.4%); three

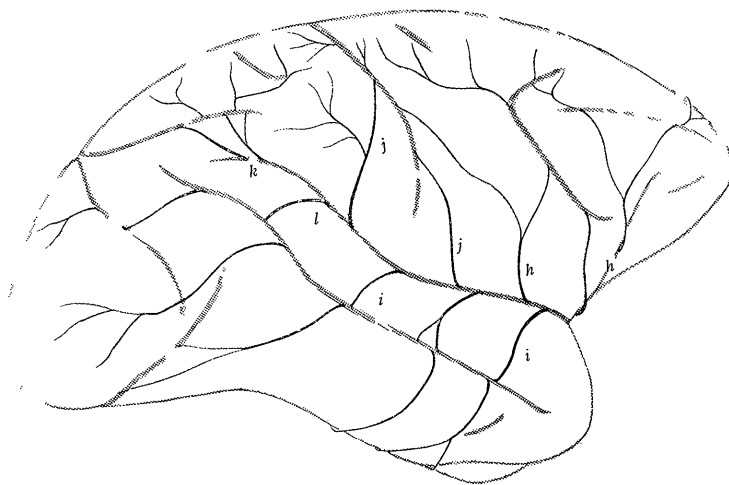


FIG. 4 Lateral view of right cerebral hemisphere

- n) Branch to Lobus frontalis
- i) Branch to Lobus temporalis
- j) Branch to Sulcus centralis and Sulcus praecentralis
- k) Branch to Lobus parietalis
- l) Branch to Sulcus lunatus and Sulcus occipitalis

branches were seen in the left hemisphere of 16 cases (84.2%) and in the right hemisphere of 16 cases (84.2%); two branches in one case (5.2%) on each side respectively; and one branch in the right hemisphere of one case (5.2%). There were three branches to the lower part of the lobus frontalis in the majority of cases in both the right and left hemispheres.

The first branch, which showed little difference by side, emerges from the lateral side of the sulcus orbitalis and in the vicinity of the lower edge of the sulcus arcuatus separates into two parts which spread out and supply the area about the sulcus rectus, upper edge of the sulcus arcuatus and the vicinity of the polus frontalis. This branch was absent only in one case (5.2%) in the right hemisphere.

The second branch ascends along the lower edge of the lobus frontalis to enter the inferior extremity of the sulcus arcuatus. This branch was absent in one case (5.2%) in the left hemisphere.

The third branch was absent in one case (5.2%) in the right hemisphere. In most cases, it ascends between the sulcus arcuatus and the sulcus centralis but there are cases in which it enters the area of the intermediate portion of the sulcus arcuatus where it sends off small branches. This artery after it enters the sulcus arcuatus sends off a small branch to the sulcus centralis and the terminal end extends to the gyrus praecentralis where it spreads out.

ii) Branches to the lobus temporalis

In most cases, there are three branches to the right hemisphere and two or three branches to the left hemisphere. Two branches, the anterior and posterior, were found in 6 cases in the left hemisphere (31.5%) and in 3 cases in the right hemisphere (15.7%); three branches, the anterior, middle and posterior, were found in 9 cases in the left hemisphere (47.3%) and in 16 cases in right hemisphere (84.2%); while four branches were found in one case in the left hemisphere (5.2%).

The anterior branch, in front, forms a demarcation line with the branch which runs toward the polus temporalis while, inferiorly, it enters the sulcus temporalis superior and descends further to form a demarcation line with the A. cerebri posterior in the sulcus temporalis inferior. The middle branch, like the anterior branch, emerges from the sulcus lateralis as a descending branch and runs obliquely downward along the gyrus temporalis superior to the sulcus temporalis superior where it further separates and spreads out toward the gyrus temporalis inferior. The posterior branch emerges from the sulcus lateralis and passes through the gyrus temporalis superior and sulcus temporalis superior to the area of the gyrus temporalis inferior where it separates. In some cases, this branch extends further to the anterior end of the sulcus occipitalis.

iii) Branches to the sulcus centralis and sulcus praecentralis

These are ascending branches emerging from the sulcus lateralis which run toward the sulcus centralis and sulcus praecentralis. There are three of these branches.

The first branch is given off from the third branch supplying the lobus frontalis. It enters the sulcus centralis and its terminal end supplies the sulcus praecentralis and the gyrus praecentralis. This artery is relatively frequently absent being found in 41.6% of the cases in the left hemisphere and in 36.4% of the cases in the right hemisphere.

The second branch emerges from the sulcus lateralis as an ascending branch and in most of the cases proceeds obliquely backward and upward along the outer surface of the lobus frontalis to the lower end of the sulcus centralis where it separates into small branches which spread out into the sulcus praecentralis and gyrus praecentralis. This artery was found in 89.7% of the cases in the left hemisphere and in 84.2% of the cases in the right hemisphere with comparatively few cases in which it is absent.

The third branch, like the second branch, leaves the sulcus lateralis and runs obliquely forward and upward as ascending branch to the intermediate portion of the sulcus centralis where it separates and supplies the sulcus praecentralis and gyrus postcentralis. This branch is comparatively frequently absent being present in 63.1% of the cases in the left hemisphere and in 46.4% of the cases in the right hemisphere.

iv) Branches to the lobus parietalis

These branches emerge from the terminal end of the sulcus lateralis. There usually are two (right hemisphere 89.6%, left hemisphere 84.4%). In addition, there are instances in which there are three branches (left hemisphere 10.4%, right hemisphere 5.2%) and four branches (5.2% in both sides, each).

These branches proceed upward along the gyrus circumflexus as ascending branches from the sulcus lateralis. The small branches which are given off in the sulcus intraparietalis enter the lobulus parietalis superior and supply the vicinity of the gyrus postcentralis.

v) Branches to the sulcus lunatus and lobus occipitalis

This is a descending branch from the terminal end of the sulcus lateralis which emerges at the lobulus parietalis inferior and passes obliquely backwards through the gyrus temporalis superior to the sulcus lunatus where it separates into the terminal branches which extend further to be distributed widely over the outer surface of the lobus occipitalis. The cases may be classified into those in which there is one branch (left hemisphere 31.2%, right hemisphere 15.7%); two

branches (left hemisphere 46.8%, right hemisphere 65.6%); three branches (left hemisphere 10.4%, right hemisphere 15.7%); and four branches (left hemisphere 5.2%).

V. A. COMMUNICANS POSTERIOR

This artery corresponds to the so-called R. posterior which is sent off backward from the A. carotis interna and it is much smaller than the R. anterior. It unites with the A. cerebri posterior which is the terminal branch of the A. basilaris. This artery runs backward, on the lateral side of the infundibulum, and unites in front of the N. oculomotorium with the A. cerebri posterior. During its course it send off small branches to the tractus opticus, the infundibulum and corpus mamillare. When the diameter of this vessel on each side is compared, they are equal in 73.4%, the left side is larger than the right side in 26.3% and left side is smaller than the right side in none of the cases. Thus, this artery is of equal size on each side in the majority of cases. There also are cases in which this A. comunicans posterior shows an islet formation (5.2% on each side) and cases in which it consists of two branches (right side 10.4%). Consequently, this artery in *Macacus cyclopsis* is small and forms a communicating branch between the A. carotis interna system in front and the A. vertebralis system in back. This condition is the same as in man (HATTA, HASEBE, ITABASHI, etc.), *Cercopithecidae* (WATTS), *Macacus fuscata* (HATTA), *Macacus rhesus* (UEDA), *Hylobatidae*, *Simia satyrus* and *Anthropithecus niger* (WATTS), HATTA has described this artery to be large and of equal size as the terminal branch of the A. basilaris in some of his cases of *Macacus cyclopsis* but no such case was found in the present study. The islet formation found in my cases is reported to be present in rare cases in man (KONDO).

VI. A. CEREBRI POSTSRIOR

This artery is a continuation of the terminal branch of the A. basilaris, which separates into these two branches of equal size to each side at the anterior edge of the pons. The respective arteries run anterolateralward in front of the radix oculomotoria, pass the lateral side of the tractus opticus and circles around the edge of the pedunculus cerebri to the base of the cerebral hemisphere. It enters the sulcus hippocampi and proceeds backward and upward along the curvature of this sulcus to this sulcus to the lower part of the splenium corporis callosi where it enters the fissura calcarina. During its course the following arteries are given off:

1. Branches given off near the origin of the A. cerebri posterior

Two branches are usually given off. One of them, which sends off a small branch to the sulcus hippocampi, runs downward and supplies the corpora quadrigemina and the corpus pineale (A. quadri-

gemina). The other, which proceeds along the main trunk of the A. cerebri posterior in the sulcus hippocampi, sends off small branches to the sulcus hippocampi and the pedunculus cerebri. It passes along the lateral side of the corpora quadrigemina and supplies the plexus chorioideus ventriculi tertii from the lower surface of the splenium corporis callosi.

2. Branches given off in sulcus hippocampi

Four to seven radiating branches are sent off. The anterior two or three branches are given off in the vicinity of the uncus gyri hippocampi and are distributed in the area of the sulcus hippocampi and polus temporalis. The one to three branches which are given off posteriorly are distributed to the gyrus hippocampi and medial surface

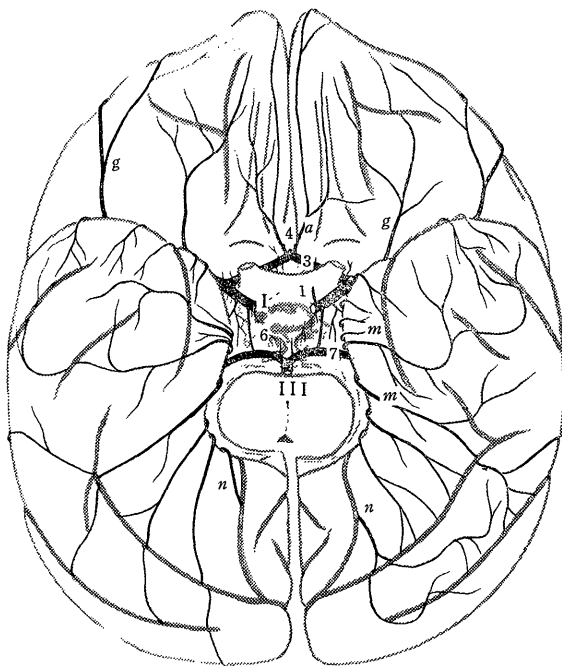


FIG. 5 Base of cerebrum after removal of the brain stem

- I) A. carotis interna
- III) A. basilaris
- 1) A. ophthalmica
- 3) A. cerebri anterior
- 4) A. cerebri anterior communis
- 6) A. communicans posterior
- 7) A. cerebri posterior
- a) A. olfactoria lateralis
- g) Rr. ascendentes anterior
- m) Branch arising from part of Uncus gyri hippocampi
- n) Branch inters to Fissura calcarina

of the lobus temporalis. Some of them pass around the edge of the brain to be distributed on the outer surface of the brain. Immediately before the A. cerebri posterior enters the sulcus calcarina, one to two branches are given off which are much larger than the above branches. They run generally parallel with the sulcus calcarina and pass through the sulcus collateralis to the sulcus occipitalis where it sends off small branches which pass around the edge of the brain to the outer surface of the lobus occipitalis.

3. The A. cerebri posterior in the sulcus calcarina

The A. cerebri posterior as it runs backward along the sulcus hippocampi, sends off small branches to the pedunculus cerebri. After it enters the fissura calcarina, it becomes the A. calcarina. This artery runs along the fissura calcarina and as it passes around the edge of the brain to the outer surface of the lobus occipitalis, it sends off small branches to the surface of the cuneus. There also is a branch which is given off in the fissura calcarina and enters the sulcus parietooccipitalis but this branch is generally poorly developed.

My findings regarding the branches and state of origin of this artery is identical to that in *Macacus fuscata* and *Macacus rhesus*. However, HATTA reported for his cases of *Macacus cyclopsis* that this artery is most often given off as a lateral branch of the terminal branch (A. communicans posterior) of the A. basilaris and was found to be a direct continuation of the terminal branch of the A. basilaris in only one case. It appears that this artery in most cases is a branch of the terminal branch of the A. basilaris in such anthropoid ape as *Hylobates*, *Simia satyrus*, *Anthropithecus niger*, *Gorilla gorilla* as well as in man.

VII. A. VERTEBRALIS

This artery enters the cranium by piercing the dura mata at the lower end of the medulla oblongata and runs toward the ventral side of the medulla oblongata. The artery on each side gradually converge upon the midline and finally unite to become the A. basilaris. There was no difference in diameter of the vessel by side. The location at which the A. vertebralis on each side are joined is generally divided equally between the upper tip of the pyramis medullae oblongatae (52.6%) and the border between the pons and medulla oblongata (47.4%). This point of junction is higher than in *Macacus fuscata* or *Macacus rhesus* and is more similar to the condition in man. Though generally in mammals, there is no remarkable difference in size by side, a tendency is said to be present in man for it to be definitely larger on the left (HATTA). In *Anthropithecus niger* also the left side is reported to be larger (HINDZE), but the findings in my cases of *Macacus cyclopsis* has demonstrated no difference by size just as in the case of *Macacus rhesus*.

1. A. spinalis anterior

This is a delicate artery which does not have a definite pattern of origin. Usually, one to three branches are given off medialward from the A. vertebralis. The arteries on each side unite in the sulcus medianus of the spinal cord to form the A. spinalis anterior which descends along this sulcus.

2. A. spinalis posterior

This artery proceeds lateralward and then descends along the dorsal surface of the medulla oblongata.

3. Further branches are seen extending lateralward which supply the area at the border of the cerebellum and medulla oblongata, the plexus chorioidea ventriculi quarti and the medial and lateral sides of the medulla oblongata.

VIII. A. BASILARIS

The A. vertebralis on each side unite at the pyramis to form the A. basilaris. It ascends along the sulcus arteriae basilaris and

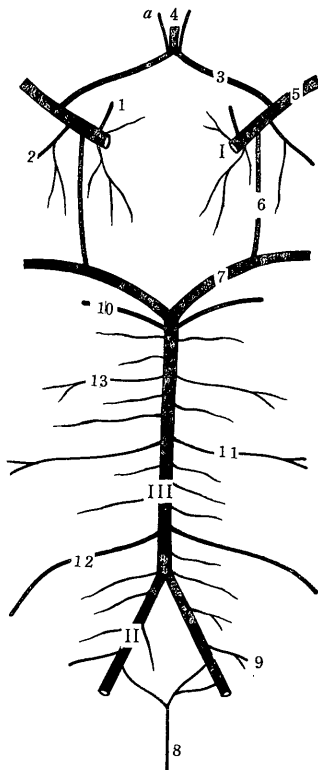


FIG. 6 The blood vessels on the base of cerebrum

- I) A. carotis interna
- II) A. vertebralis
- III) A. basilaris
- 1) A. ophthalmica
- 2) A. chorioidea anterior
- 3) A. cerebri anterior
- 4) A. cerebri anterior communis
- 5) A. cerebri media
- 6) A. communicans posterior
- 7) A. cerebri posterior
- 8) A. spinalis anterior
- 9) A. spinalis posterior
- 10) A. cerebelli superior
- 11) A. cerebelli inferior anterior
- 12) A. cerebelli inferior posterior
- 13) Rami ad pontem
- a) A. olfactoria lateralis

separates into its terminal branches to each side at the anterior edge of the pons. Its course is almost always linear. It is very rarely curved (5.2%). The terminal branch passes along the medial side of the radix oculomotoria toward the upper lateral side and becomes

the A. cerebri posterior. There were cases in which union of the A. vertebralis has occurred earlier on the medulla oblongata with separation again into two parts and reunion at the border between the medulla oblongata and pons for the formation of the A. basilaris (10.4%), but this is considered to be evidence that this artery is formed by the union of the fundamental artery on each time during the embryonic period. During its course, the following branches are sent off.

1. A. cerebelli superior

This artery which is of equal size on each side in almost all cases (84.4%) is given off near the origin of the terminal branch of the A. basilaris and runs lateralward behind the radix oculomotoris. As it passes around behind the pons to the superior surface of the cerebellum, it gives off small branches to the dorsal surface of the pedunculus cerebri and upper edge of the pons. During its course, one or two small branches are sent to the vicinity of the colliculi inferioris of the corpora quadrigemina and a further comparatively well developed branch is given off to the region in front and below the flocculus.

2. A. cerebelli inferior anterior

This artery arises from the A. basilaris at the base of the pons and runs lateralward in front of the radix of the N. abducens. It runs lateralward along the lateral edge of the pons and separates into two branches above the flocculus. The upper branch becomes the A. auditiva interna while the lower branch extends to the lower part of the flocculus. There usually is no difference in the size of the this artery by size at the origin. When the length of the A. basilaris from the point of junction of the A. vertebralis on each side is separated into 10 segments, the origin of this artery is in the fifth segment in 63.2%; in the seventh segment in 36.8%; and in the eighth segment in 10.4%. Thus, this artery arises usually at about the middle of the A. basilaris. Review of the location of this artery in relation to the radix of the N. abducens shows that it is anterior to the radix of the N. abducens on both sides in 89.6%; posterior on both sides in 5.2%; and anterior on the right side but posterior on the left side in 5.2%. Hence, this artery on both side most commonly runs anterior to the radix of the N. abducens which is entirely different from the condition in man where it runs posteriorly as a rule. There were cases (5.2%) in which this artery was absent, but in these cases the A. cerebelli inferior posterior was highly developed compensated the absence of the A. cerebelli inferior anterior.

3. A. cerebelli inferior posterior

This artery arises slightly above the point of junction of the A

vertebralis on each side. It runs lateralward ventral to the radix of the N. abducens and descends along the lateral edge of the medulla oblongata to the dorsal surface of the medulla oblongata. Before it reaches the posterior surface of the cerebellum, it separates into two branches, one of which continues to ascend along the posterior surface of the cerebellum while, the other branch passes through the plexus chorioidea ventriculi quarti to which small branches are sent off. The origin of this artery is from the A. basilaris, most commonly near the point of junction of the A. vertebralis of each side which is different from the condition in man in which it arises from the A. vertebralis. The origin may be classified into those in which the artery of each side arise symmetrically from the A. basilaris (46.8%); those in which it arises on both sides from the A. vertebralis (5.2%); that in which the origin on the left side only is from the A. vertebralis (10.4%); and that in which only the right side arises from the A. vertebralis (5.2%). In addition, there are cases in which it is absent on both sides (5.2%); absent on the right side only (15.6%); and cases in which it is absent on the left side (5.2%). In these cases in which this artery is absent, the A. cerebelli inferior anterior is well developed, compensating the absence as is the case in *Anthropithecus niger* (HINDZE) and man (HATTA).

4. Rami ad pontem

These branches, either short or long, arise from the A. basilaris and there usually are three to five. The short branches are distributed to a small area of the pons while the long branches run around the lateral edge of the pons to the dorsal surface of the pons and the longest of them extends as far as the corpora quadrigemina.

IX. CIRCULUS ARTERIOSUS CEREBRI

The branchings of the A. carotis interna and A. basilaris at the base of the brain, described above, form the so-called arterial circle of Willis as in other primates. The A. carotis interna, before it gives rise to the A. cerebri media along with the A. cerebri anterior, A. communicans posterior and A. cerebri posterior forms a perfect arterial circle. However, since in rare cases there is an A. communicans anterior connecting the A. cerebri anterior prior to the union of this artery on each side, the circulus arteriosus cerebri of *Macacus cyclops* may be classified into two types. In other word, there is the type in which the A. communicans anterior does not take part in the formation of the circulus arteriosus (type I) and that in which it is associated with the formation (type II). My cases of *Macacus cyclops* were of type I in 17 cases (89.6%) and of type II in 2 cases (10.4%). It appears that in primates, specific types may be classifi-

ed for each family as to whether the A. communicans anterior takes part in the formation of the so-called circulus arteriosus. Review of past literature reveals that in man there almost always is the A. communicans anterior and a circle is formed by its connection of the A. cerebri anterior of each side. However, in *Pongidae*, occasionally in *Simia satyrus* (BOLK) and *Anthropithecus niger* (WATTS), the A. communicans anterior is absent but in generally the state is very similar to the type seen in man, belonging to the type II of my cases of *Macacus cyclopsis* (WATTS, ROTHMAN, HINDZE, SPERINO, SHELLSHEAR, etc.). In contrast to this in *Hylobatidae* the state is type II (SPERINO, WALDEYER) and sometimes type I (WATTS, ROTHMANN). Further, in lower monkey such as *Cercopithecidae* and *Cebidae*, the A. communicans anterior is never found and is the so-called type I (WATTS, STANUIUS, THEILE, ROTHMAN, HATTA, UEDA, etc.). As is evident from my findings, there is in addition to type I, a few cases of type II or the human type, at least in the *Macacus cyclopsis* that I studied. The reason for the absence of type II in literature is presumed to be due to the insufficient number of cases studied.

SUMMARY

The following findings were obtained in the gross anatomical inspection of the distribution of arteries in the brain of *Macacus cyclopsis*. The material consisted of 38 cerebral hemispheres from both sides of 19 adult animals.

The arterial system of the brain of *Macacus cyclopsis* is supplied by the A. carotis interna and A. vertebralis.

1. A. carotis interna

This artery, which is much similar to that in man and other primates, extends to the chiasma opticum and lobus temporalis and, after giving off the A. ophthalmica and A. chorioididea anterior, it separates into its terminal branches, the A. cerebri anterior and A. cerebri media, at the lateral side of the N. opticus. In addition, the A. communicans posterior which anastomoses with the A. cerebri posterior is given off.

2. A. cerebri anterior

This artery, which arises as a lateral branch from the A. carotis interna, enters the fissura longitudinalis cerebri and unites with its opposite mainly in front of the area subcallosa to form the A. cerebri anterior communis. During its course, the A. olfactorium lateralis and the Rami perforantes are given off. After the formation of the

A. cerebri anterior communis, branches are sent off to the medial surface of the lobus frontalis, sulcus centralis, sulcus postcentralis and sulcus intraparietalis as it passes around behind the splenium corporis callosi to become the terminal branch, the A. corporis callosi, which further separates into two parts which are distributed to the cuneus, sulcus parietooccipitalis, the sulcus lunatus, sulcus calcarina and to the outer surface of the lobus occipitalis after it emerges to the outer surface.

3. A. communicans anterior

Soon after entering the fissura longitudinalis cerebri, the A. cerebri anterior of each side usually unite to form the A. cerebri anterior communis. In rare cases, however, prior to this junction of the artery on each side, a communicating branch, the A. communicans anterior, which connects the A. cerebri anterior of each side is seen.

4. A. cerebri media

This artery which appears to be the direct continuation of the A. carotis interna enters the sulcus lateralis and passes around the edge of the brain to the lower surface of the lobus occipitalis. During its course, branches are sent off which supply the substantia perforata anterior, surface of orbitus, sulcus hippocampi, medial surface of polus temporalis, upper and lower surfaces of the lobus frontalis, lobus temporalis, sulcus centralis, sulcus praecentralis, lobus occipitalis and sulcus lunatus.

5. A. communicans posterior

This artery is given off posteriorly from the A. carotis interna and is a communicating branch with the terminal branch of the A. basilaris, the A. cerebri posterior. In rare cases islet formation is noted.

6. A. cerebri posterior

This artery is considered to be the extension of the A. basilaris. At the anterior edge of the pons, it separates into the A. cerebri posterior to each side and runs lateralward in front of the radix oculomotoria to the base of the cerebral hemisphere. It further enters the sulcus hippocampi, proceeds backward and upward and enters the fissura calcarina from the lower part of the splenium corporis callosi to be widely distributed to the posterior part of the lobus occipitalis.

7. A. vertebralis

This artery on each side of equal size and unite at the area of junction of the pons and medulla oblongata to form the A. basilaris. From this artery are given off the A. spinalis anterior, the A. spinalis posterior and branches to the medulla oblongata and plexus chorioidea ventriculi quarti.

8. A. basilaris

This artery is formed by the union of the A. vertebralis on each side. It ascends along the sulcus arteriosus basilaris and at the anterior edge of the pons separates into its terminal branches, the A. cerebri posterior, to each side. In rare cases islet formation is noted but this is considered to represent the process of development of this artery. From this artery is given off the A. cerebelli superior, the A. cerebelli inferior anterior, the A. cerebelli inferior posterior and the rami ad pontem.

9. Circulus arteriosus cerebri

The branchings of the A. carotis interna and A. basilaris at the base of the brain form the so-called circulus arteriosus cerebri, but in *Macacus cyclopsis* because of the rare presence of the A. communicans anterior, it may be classified into two types; one in which the A. communicans anterior is related to the formation of the circulus arteriosus cerebri, and the other in which the A. communicans anterior is not associated. The latter is the common type.

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